Clouds and the Earth’s Radiant Energy System (CERES)

Validation Plan

Convolution of Imager Cloud Properties With

CERES Footprint Point Spread Function

(Subsystem 4.4)

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4.4.1 INTRODUCTION

The primary purpose of the ATBD Subsystem 4.4 is to locate the imager pixels that are within a CERES footprint and record the cloud statistics over the footprint on the SSF data product. The CERES footprint or the field that is viewed by CERES is also viewed by an imager on the same spacecraft. Subsystem 4.1 - 4.3 in the ATBD is devoted to defining cloud properties over the field at each imager pixel on a 4 km grid or less. Since the CERES measurement is defined as the convolution of the instrument Point Spread Function (PSF) over the radiation field, an effective cloud parameter is defined as the PSF weighted average over the footprint.

The main objective of this section is to validate the PSF which defines the location and size of the CERES footprint and the weighting of the cloud parameters over the footprint.

4.4.1.1 Measurement and science objectives

The CERES broadband radiance measurements will be processed in conjunction with collocated narrowband imager data. Since the spatial resolution of the imager data is much higher than the CERES data, many imager pixels will be within a single CERES footprint. The imager data consists of several narrowband channels which makes possible a high quality cloud retrieval (Subsections 4.1 - 4.3) over the CERES footprint. This detail definition of the cloud condition over the footprint permits more accurate inversion of radiance to flux at the top of the atmosphere (TOA) (Subsection 4.5) and also influences the estimate of the surface flux (Subsection 4.6). The imager on TRMM is the VIRS and the imager on EOS is MODIS.

4.4.1.2 Missions

The CERES scanners will be launched aboard the TRMM spacecraft and the EOS AM and PM platforms (see Section 1.1.2)

4.4.1.3 Science data products

The science data product from this section is the Single Satellite Footprint Product (SSF) (ATBD Section 4.0 App. B-3) which contains measurement time, viewing geometry, CERES radiances, imager radiances, scene type, TOA fluxes, surface fluxes, and cloud statistics. The measurement time and viewing geometry are validated in Section 1.0. The CERES radiances are validated in Section 1.0. The imager data will be validated by their respective science teams. The validation of the inversion scene type and TOA fluxes are discussed in Subsection 4.5 and the surface fluxes in Subsection 4.6. The cloud parameters are validated in Subsections 4.1 - 4.3 and their uncertainties are not changed by averaging over the CERES footprint. This section will concentrate on validating the PSF.

4.4.2 VALIDATION CRITERION

4.4.2.1 Overall approach

The PSF is measured prelaunch as part of the instrument development (ATBD Section 1.2.2). The in-flight validation of the prelaunch PSF is discussed in this section since it involves regressing CERES data and imager data for individual footprints.

The two main parameters associated with the prelaunch PSF are its centroid and its dispersion. Since the CERES measurement is defined as the convolution of the true PSF over the radiation field, our prelaunch PSF is valid if it gives the best agreement between the CERES and imager data. Any displacement of the centroid or change in the dispersion of the prelaunch PSF should cause this data agreement to deteriorate. One of the SSF parameters is the weighted average imager data over the CERES footprint where the weighting function is the PSF. We can validate the PSF by regressing the CERES broadband measurements on the mean imager data using the prelaunch PSF. We will actually regress the shortwave CERES channel on the 0.6 μm channel during daytime and the total channel on the 11.0 μm channel at night. We expect the validation conclusions to be the same for both shortwave and longwave but examine both as part of the validation. If the shortwave and longwave case give different results, then further studies would be warranted.

A single regression will yield a slope, intercept, and variance of the data about the regression line. We can then increment the centroid of the PSF relative to the optical axis and repeat the regression. We would expect the CERES and imager data to match the best (minimum variance) when the centroid of the PSF is at its prelaunch position. If this is not the case and we find a statistically significant offset in either the along-scan or the cross-scan direction that minimizes the variance, then there is a mislocation. Either the CERES data is mislocated, or the imager data is mislocated, or the PSF centroid is different than measured prelaunch. The imager with its high resolution and multiple channels is probably the least likely to be mislocated. On the other hand the CERES data has been located at the PSF centroid and validated with a coastline detection technique (Section 1.4.6). Thus, a centroid offset correction should be made only if it is within the uncertainty of the coastline technique.

Having determined the PSF centroid, we next increment the dispersion to find the best agreement of the CERES data to the imager data. If a statistically significant change in dispersion is found, then we should change the PSF.

The dispersion of the PSF is incremented by expanding or contracting the coordinate system. We define the PSF as $f(x,y)$ where x is the along-scan angle ($-a \le x \le b$) and y is the cross-scan angle ($-c \le y \le c$) so that $x=y=0$ is the centroid. We then increment the PSF by α and β where the new PSF is $f(x/\alpha, y/\beta)$ where $-\alpha a \le x \le \alpha b$ and $-\beta c \le y \le \beta c$ and where α and β are near 1. The best agreement is the α and β that minimize the regression variance.

4.4.2.2 Sampling requirements and trade-offs

The validation of the CERES PSF requires CERES and imager data. A month of data should be sufficient for this study.

4.4.2.3 Measures of success

It is not clear how accurately the PSF centroid can be determined by regressing CERES data on imager data. Prelaunch studies with ERBE and AVHRR data will be used to establish the regression technique and its expected accuracy. We expect the regression technique to yield better accuracy than the 6 km uncertainty in the coastline crossing technique (section 1.4.6). But, the regression technique accuracy is not expected to reach the 1 km uncertainty in the spacecraft ephemeris (section 1.4.6).

The dispersion of the PSF is measured prelaunch and its uncertainty established. The regression technique will improve on this uncertainty if it can determine a significant dispersion change that is within the prelaunch uncertainty. The importance of the PSF dispersion is in setting the size of the CERES 95% energy footprint and the averaging weights for the cloud parameters. It does not effect the radiance measurements and only indirectly the TOA flux estimate through the ADM scene types used to convert from radiance to flux.

4.4.3 PRE-LAUNCH ALGORITHM TEST/DEVELOPMENT ACTIVITIES

4.4.3.1 Field experiments and studies

4.4.3.2 Operational surface networks

4.4.3.3 Existing satellite data

The regression technique to determine the centroid and dispersion of the PSF will be developed prelaunch with ERBE and AVHRR data. Is it better to use shortwave or longwave data? Should we use nadir or limb footprints or all footprints? It would seem that heterogeneous scenes would be better than homogeneous scenes because they are more sensitive to the PSF increments. These questions will be resolved with prelaunch sensitivity studies.

4.4.4 POST-LAUNCH ACTIVITIES

4.4.4.1 Planned field activities and studies

4.4.4.2 New EOS-targeted coordinated field campaigns

4.4.4.3 Needs for other satellite data

The regression technique will be implemented post-launch using VIRS imager data on TRMM and MODIS imager data on EOS. A month of data should be sufficient for this validation study.

4.4.4.4 Measurement needs at calibration/validation sites

4.4.4.5 Needs for instrument development

4.4.4.6 Geometric registration site

4.4.4.7 Intercomparisons

4.4.5 IMPLEMENTATION OF VALIDATION RESULTS IN DATA PRODUCTION

4.4.5.1 Approach

We will apply the regression technique to each day of data separately. After one month we should have 30 independent estimates of the dispersion parameter, say α. From these 30 values we can determine the mean and standard deviation and test if the mean is statistically significantly different than 1. If significance is found, and if α is within the uncertainty of the measured PSF, then we would correct the PSF with the approval of the CERES Science Team.

4.4.5.2 Role of EOSDIS

The regression of CERES data on imager data will be done off-line.

4.4.5.3 Plans for archival of validation data

4.4.6 SUMMARY

We assume the imager data is highly located so that we can regress CERES data on imager data and determine the empirical location and dispersion of the PSF that gives the best agreement. If the empirical location is outside of the uncertainties of the coastline crossing technique and the satellite emphemeris, then we should question the accuracy of the imager data location.

CERES VALIDATION

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DATA PRODUCTS/PARAMETERS

CERES Product: SSF. Parameter: point spread function (PSF) which sets location and size of CERES footprint and averaging weights.

MISSIONS

TRMM, EOS AM-1, EOS PM-1

APPROACH

Regress CERES data on imager data and minimize variance with PSF centroid and dispersion.

PRE-LAUNCH

Develop regression technique of locating the best fit of CERES and imager data and develop statistics of minimum variance point. Use ERBS and AVHRR data for pre-launch studies.

POST-LAUNCH

Apply regression technique to first month of CERES data from TRMM and EOS AM.

EOSDIS

All validation tests off-line.